HARMFUL OVEREXPOSURE TO RADIO FREQUENCY ELECTROMAGNETIC FIELDS (RF-EMFS)

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Introduction

We are increasingly surrounded by radio frequency electromagnetic fields (RF-EMF) in our daily lives. While the majority of these EM fields pose little direct threat to our health and welfare, those which are more powerful or at higher frequencies may. The prehospital patient population (both rural and urban) is at risk of overexposure to radio frequency electromagnetic fields (RF-EMF) in multiple areas of industry and in relation to commercial applications of this technology. Furthermore, with ongoing development of this technology as a weapon for the military or civilian law enforcement cohort it is likely that in the years to come, more patients will be affected by this type of weaponry. The effects of RF-EMF are not fully understood on all body systems, and a comprehensive history and examination can inform the need for appropriate immediate and subsequent patient management.

Background

Electric or magnetic fields (electromagnetic fields – EMFs) are areas of energy or radiation produced by electricity. The electromagnetic forces within an EMF are caused by radiation of varying types. The electromagnetic radiation spectrum (Figure 1) encompasses a wide range of radiation, from the high frequency ionizing radiation portion of the spectrum, where the radiation can directly damage cells and DNA, to the low- and mid-frequency portions of the spectrum, which contain emissions such as radio waves, or Radio Frequencies (RF). Paramedics are well aware of the dangers of ionising radiation, and these are covered in emergency responder Chemical, Biological, Radiological and Nuclear (CBRN) training; however, the hazards associated with non-ionising radiation in the Radio Frequency (RF) range are less well taught and understood.

The American Joint Trauma System (JTS) has recently published a Clinical Practice Guideline (CPG) detailing the assessment and management of patients exposed to high levels of RF-EMF (1). In the United Kingdom, while there are regulations and government guidance around reducing exposure to EMFs (2; 3) there are not, to the author's knowledge, readily available clinical practice guidelines for the acute management of those overexposed to RF-EMFs.

As prehospital professionals we should be aware of the many potential sources for exposure to RF-EMF in our patients' day-to-day lives. Radio and television broadcasting systems, radar stations, often those sited in remote and rural locations to avoid risk to the public, and multiple applications in industry (*and the military*) have the potential to overexpose individuals to harmfully high energy RF-EMF (Table 1). Beyond these, RF-EMF is being increasingly investigated as a potential weapon, both for the battlefield and for civilian crowd-control or public order (4; 5). As a weapon they are often used as Active Denial Systems (ADS), and are known as Directed Energy Weapons (DEWs), but are sometimes colloquially termed *Heat Rays*. These weapons aim a 95 GHz beam at combatants or civilians up to 250m away to induce significant heat build-up in the skin of targeted individuals within seconds (6), and prolonged exposure causing burns. While DEWs *may* have a place in war and riot control, there is also the potential for their use as a device of torture or of inflicting punishment and the ethical considerations of such devices are still under discussion (7).

Directed Energy Weapons (DEWs)
Electrical circuits exceeding 100 Amps
Industrial electrolysis
Industrial microwaves
Microwave energised lighting
Military applications
Radar
Radio and television broadcasting systems

Table 1) Potential sources of harmful levels of RF-EMF. Adapted from (8; 1)

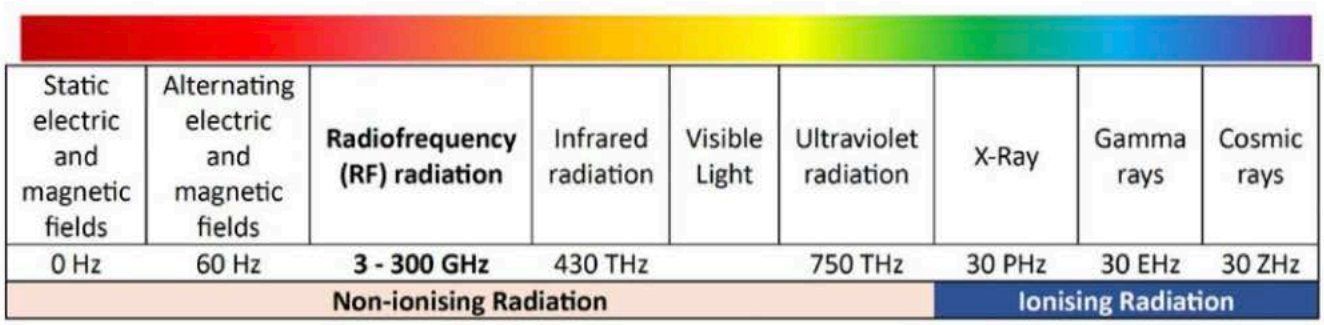

Figure 1

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Mitigating the Effects of RF-EMF Exposure

Guidance exists to limit exposure to RF-EMF both at a population level and an individual one in the occupational context. This is due to concerns that high levels of RF-EMF exposure have deleterious effects on one's health. Unfortunately, measuring direct RF-EMF exposure is difficult and expensive (8); work is underway to develop affordable and wearable RF exposure detectors, however these are not yet widely available (9). This makes it a challenge to monitor and enforce Exposure Limit Values (ELVs) for RF-EMF. Despite this, there are ELVs in terms of avoiding adverse health effects (Health-Effect ELVs) and unpleasant sensory stimuli (Sensory-Effect ELVs) (8). It is worth noting that these limits do not apply to the military or anyone working with the Ministry of Defence (8). Nearly all day-to-day electronics (e.g. WiFi, Bluetooth, mobile phones & computer equipment) are incapable of exposing individuals to EMF levels in excess of these ELVs but as noted earlier (Table 1) there are many commercial or industrial sources of harmful levels of RF-EMF.

It can be challenging to fully mitigate the risks from RF-EMF through the use of Personal Protective Equipment (PPE), especially with technology rapidly evolving in this area (9). Shielding is likely to be the answer in most situations where EMF pose a risk to personnel, but a more straightforward method is to remove yourself and the patient from the potential source to the greatest distance and as quickly as possible (1).

Acute Injuries

Patients suspected of being overexposed to RF-EMF should receiving comprehensive assessment. This should include a detailed history, vital signs monitoring and physical examination to elicit all signs and symptoms (Table 2). The Joint Trauma System CPG (1) recommends that the history-taking should seek to elicit the following from the patient, or as collateral history:

- Description of the event
- Suspected or confirmed source of exposure
- Duration of exposure
- Distance from the source
- Type of emitter
  - Transmission power (average and peak)
  - Transmission frequency
  - Transmission type: continuous or pulsed
- Was a part or whole of the body affected
- Signs and symptoms

Physical examination should be thorough and include in-hospital ophthalmological examination and a cranial nerve and peripheral nerve examination and, if symptoms relating to the heart are suspected, a 12-lead electrocardiogram should be undertaken (10; 1). If there is a history indicative of significant exposure or symptoms suggest hyperthermia, a core temperature should be measured (1; 10). Signs or symptoms indicative of organ dysregulation should prompt laboratory investigation in the usual manner.

- Burns
- Compartment syndrome
- Diarrhoea
- Headache
- Hyperthermia
- Interaction with implanted medical devices
- Malaise
- Nausea
- Neuropathy
- Painful nerve impulses
- Skin erythema
- Visual disturbance

Table 2) Symptoms of overexposure to RF-EMF. Adapted from (1; 10)

Burns

It has been suggested that burns resulting from exposure to RF-EMF may be deeper than they appear, with internal structures such as muscles and organs at risk of thermal injury (10) (Table 3). Detection of such damage may be extremely challenging, and may only become evidence hours or days later (10). Burns caused by exposure to RF-EMF should be assessed and treated in the usual way. The majority of superficial RF-EMF induced burns will heal without intervention (1).

Frequency GHz	Penetration depth of human skin (mm)	Frequency Domain
0.3-3	Up to 30	Ultra High Frequency (UHF)†
6	8.1	Super High Frequency (SHF)*
10	3.9	
30	0.92	Extremely High Frequency (EHF)**
60	0.49	
100	0.35	
300	0.23	

Key:
†=Domestic microwave ovens / mobile phones / bluetooth;
*= Satellite phones / Wireless LANs;
**Airport security scanners / military radar / 5G

Table 3) Frequency and skin depth penetration. Adapted from (11; 1; 12)

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Compartment Syndrome

Overexposure may cause heating to muscles or other deep tissue without obvious overlying burns, this can include damage and resultant thrombosis of the vasculature supplying muscle compartments. This direct damage or ischaemia can result in compartment syndrome (13; 1).

Hyperthermia

Excessive exposure to RF-EMF can heat biologic tissue; the type of heating that occurs depends on amount and type of RF-EMF exposure (10). Temperature measurement and ideally constant monitoring of core temperature is helpful in assessing these patients (1). Hyperthermia occurring from EMF exposure, presenting in the form of heat exhaustion or heat stroke, should be treated in the usual way (1). This can be considered an exertional heat stroke in terms of the approach to treatment, i.e. rapid cooling by whole body immersion in cold water if required.

Ocular Injuries

Ocular injuries from RF-EMF overexposure can include keratitis, iritis, haemorrhage and optic nerve injury and that these injuries may result from much lower energy level exposure than required to cause notable injury to the skin (14). Cataracts can occur week after exposure, with an early ophthalmic assessment providing a useful pre-injury baseline. Best practices in relation to managing this aetiology of ocular injuries is uncertain (1), and standard guidelines should be followed until expert advice can be sought.

Neuropsychiatric Symptoms

It has been postulated that exposure to RF-EMF has the potential to cause neuropsychiatric sequala beyond the expected repercussions of heating brain tissue (14). While these symptoms are still poorly understood, and are likely confounded by the nocebo effect (15), they can include a wide range of symptoms including "headaches, dizziness, and emotional changes to seizures and altered consciousness" (14). Use of RF-EMF DEWs specifically to induce neuropsychiatric symptoms as a *Neuroweapon* is poorly understood but is certainly an area of growing concern (9) (Table 4). There are no specific treatment recommendations yet for RF-EMF induced neuropsychiatric symptomatology (1).

A weapon that specifically targets the brain or central nervous system with the intent to affect the target's mental capacity, mental state or behaviour in a manner which can be predicted by the aggressor.

Table 4) A definition of Neuroweapons. Adapted from (15; 9)

Long-Term Effects

It appears unlikely that RF-EMF exposure increases cancer risk, but given the rate of propagation for sources of such non-ionising radiation, further studies into the long-term outcomes in this regard will be needed (15). Equally, there does not appear to be an adverse effect on fertility from RF-EMF exposure. It has been highlighted however that there appears to be a widespread nocebo effect relating to perceived or actual RF-EMF exposure, which may account for some of the presenting symptoms (15).

Conclusion

Harmful exposure to Radio Frequency Electromagnetic Fields (RF-EMFs) is likely to become more common in our increasingly technologically advanced society. Furthermore, if development continues into the use of such devices as crowd control measures, civilian healthcare providers are inevitably going to come into contact with patients who have been exposed to such Directed Energy Weapons (*Heat Rays*) and RF-EMF exposure must be included in any CBRN education moving forwards. Having a clear strategy for history-taking and the initial examination and management of such patients will prove valuable in providing the best care possible, but also for documenting such exposures in order to build the evidence-base relating to this issue moving forwards. As a new and emerging threat to health, Radio Frequency Electromagnetic Fields (RF-EMFs) may appear more science-fiction than clinical priority but for those working in industry, public order or the military, or providing care to these groups, fiction may become reality faster than we anticipate.

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